06-18-01

JC04 Rec'd PCT/PTO 15 JUN 2001

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TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35.U.S.C. 371

EXPRESS MAIL LABEL No	DATE
EF321685410	June 15, 2001

ATTORNEY'S DOCKET NO
A32795-PCT-USA - 072448.0327

U S APPLICATION NO
09/868471

INTERNATIONAL APPLICATION NO	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/US99/26946	November 16, 1999	

TITLE OF INVENTION
Ampere A. Tseng

APPLICANT(S) FOR DO/EO/US
CRUCIBLE AND SPINDLE FOR A VARIABLE SIZE DROP DEPOSITION SYSTEM

Applicant herewith submits to the United States Designated /Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(I).
4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [X] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [ ] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [X] A copy of the International Search Report (PCT/ISA/210)
   a. [X] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [X] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. [ ] A copy of the International Preliminary Examination Report (PCT/IPEA/409)
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [ ] A FIRST preliminary amendment.
    [ ] A SECOND or SUBSEQUENT preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [X] Other items or information:
    a. [X] a copy of the International Search Report (PCT/ISA/210)
    b. [ ] a copy of the International Preliminary Examination Report (PCT/IPEA/409)
    c. [X] PCT application No. PCT/US99/26946 was published in English under publication number WO 01/36136 on May 25, 2001.

INTERNATIONAL APPLICATION NO. PCT/US99/26936	INTERNATIONAL FILING DATE November 16, 1999	PRIORITY DATE CLAIMED

17. [X] The following fees are submitted:

Basic National Fee (37 CFR 1.492(a)(1)-(5):

Neither international preliminary examination fee (37 CFR 1.482)

Nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO (1.492(a)(3)) $1,000.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO (1.492(a)(5) $860.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO(1.492(a)(2)) $710.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) (1.492(a)(1)) $690.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) $ 100.00

CALCULATIONS PTO USE ONLY

ENTER APPROPRIATE BASIC FEE AMOUNT =	$860.00	
Surcharge of $130.00 for furnishing the oath or declaration later than [ ] **20** [ ] **30** months from the earliest claimed priority date (37 C.F.R. 1.492(e)).	$0.00	

Claims	**Number Filed**	**Number Extra**	**Rate**	$	
Total Claims	3 -20=		X $ 18.00	$	
Independent Claims	1 -3=		X $ 80.00	$	
Multiple dependent claim(s) (if applicable)			+ $270.00	$	
			TOTAL OF ABOVE CALCULATIONS =	$860.00	
Reduction by ½ for filing by small entity, if applicable				$430.00	
			SUBTOTAL =	$430.00	
Processing fee of $130.00 for furnishing the English translation later than [ ] **20** [ ] **30** months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
			TOTAL NATIONAL FEE =	$	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$ 0.00	
			TOTAL FEES ENCLOSED =	$430.00	
				Amt. refunded	$
				charged	$

a. [X] A check in the amount of $430.00 to cover the above fees is enclosed.

b. [ ] Please charge our Deposit Account No. 02-4377 in amount of $___ to cover the above fees. A copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 02-4377. A copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

BAKER BOTTS L.L.P.
30 Rockefeller Plaza
New York, New York 10112-4498

Marta E Delsignore
Signature

June 15, 2001
Date

32,689
Registration No.

CRUCIBLE AND SPINDLE FOR A VARIABLE SIZE DROP DEPOSITION SYSTEM

SPECIFICATION

FIELD OF THE INVENTION

The present invention relates to an apparatus for manufacturing a three-dimensional object. More specifically, the present invention relates to an improved crucible and spindle design for a drop deposition system.

BACKGROUND OF INVENTION

Manufacturing processes utilizing deposition techniques have been developed for rapid prototyping of three-dimensional parts and tooling. For example, in United States Patent No.'s 5,301,863, 5,301,415, 5,207,371 and 5,286,573 to Prinz et al., conventional systems and methods are disclosed for manufacturing three-dimensional objects by forming using thermal spray or weld deposition techniques to deposit material layers on a work surface. See also United States Patent No. 5,266,098 to Chun et al.

Drop generators have also been developed and applied to the rapid prototyping of three-dimensional objects. See P. F. Jacobs, Rapid Prototyping and Manufacturing, ch. 16 (Society of Manufacturing Engineers 1992). In a conventional drop generator of this type, molten metal is ejected as a uniform laminar liquid jet from a circular injector or nozzle located at the bottom of a heated reservoir. The liquid jet is then broken into a series of uniformly sized drops by using a fixed diameter injector and an applied oscillation force near the injector or nozzle orifice. The uniformly sized drops are then deposited in layers on a substrate surface where they solidify to form the desired three-dimensional metal product.

With such techniques, resulting metal products can be designed to have fine, equiaxed micro-structures without manufacturing defects such as porosity or alloy segregation. See C.-A. Chen, P. Acquaviva, J.-H. Chun and T. Ando, "Effects

of Droplet Thermal State on Deposit Microstructure in Spray Forming," Scripta Materiala, vol. 34, pp. 689-696 (1996); J.-H. Chun and T. Ando, "Thermal Modeling of Deposit Solidification in Uniform Droplet Spray Forming," Proceedings of the 1996 NSF Design and Manufacturing Grantees Conference, pp. 353-354 (Society of Manufacturing Engineers 1996). Other conventional systems, such as disclosed by Sterrett et al. in United States Patent No. 5,617,911, use electromagnetic fields to control the deposition of uniform size drops.

The manufacturing capabilities of conventional drop generators, however, remain limited by the relatively small range of possible drop sizes. Greater variability in the drop size is desired to allow more efficient rapid prototyping by allowing the mass flux to be set according to the outline geometry and desired internal micro-structure of the product at a given point. Despite the variability of external oscillation, the possible range of drop sizes from a conventional drop generator is limited by the fixed injector diameter, which is typically less than one millimeter.

SUMMARY OF THE INVENTION

Therefore, a principle object of the present invention is to provide an apparatus for manufacturing a three-dimensional object utilizing a continuously variable diameter liquid jet to create variable drop sizes.

Another object of the present invention is to provide an apparatus for manufacturing a three-dimensional object utilizing an improved crucible and spindle apparatus for creating variable diameter liquid jets from which variable diameter material drops are formed.

A crucible and spindle apparatus is provided that substantially overcomes the aforedescribed limitations and inadequacies of those used in conventional drop deposition systems. In accordance with a preferred embodiment of the present invention, the apparatus includes a crucible for holding a reservoir of molten material and a conically-shaped orifice having a fixed diameter disposed in the bottom of the crucible through which a jet of the molten material flows towards the substrate. An oscillating mechanical member having a conically-shaped head is provided for varying the effective size of the orifice and breaking the flow of molten

material into the molten material drops. The conically-shaped head includes a slanted radial portion and a tip portion extending through the orifice, wherein the effective diameter d_{eff} of the orifice and thus the jet is defined by the equation $d_{eff} = [d_0^2 - (d_0 - \delta \tan \theta)^2]^{1/2}$. As explained in detail below, d_0 represents the fixed diameter of the crucible orifice, δ represents the amount of the tip portion extending through the crucible orifice, and θ represents a slant angle corresponding to the slanted radial portion of the conically-shaped head.

Further objects, features and advantages of the invention will become apparent from the following detailed description taken in conjunction with the accompanying figures showing illustrative embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

For a complete understanding of the present invention and the advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings in which like reference numbers indicate like features and wherein:

FIG. 1 is a sectional view of a drop deposition system for manufacturing a three-dimensional object which incorporates the present invention;

FIG. 2 is a sectional view of a conically-shaped orifice and corresponding conically-shaped spindle head in accordance with a preferred embodiment of the present invention; and

FIG. 3 is a sectional view of a crucible structure in accordance with a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates a preferred embodiment of a drop deposition system 100 for manufacturing three-dimensional objects. The system is used to form variable size material drops from a variable size material jet, and is similar to the system described in co-pending United States Application Serial No. 09/010,923, which is hereby incorporated by reference in its entirety.

As shown in FIG. 1, the drop deposition system 100 includes a control

section 20, a heating section 30 and a deposition section 40. The heating section 20 includes a crucible 1 for holding molten materials such as metals or wax deposited therein. The crucible 1 includes a fixed size orifice 1a, and is preferably provided with a corresponding heating device 4 for controlling the temperature of the molten material and a thermocouple 3 for monitoring the temperature of the molten material. An oscillating, position controlled spindle 5 is provided within the crucible 1 for agitating the molten material within the crucible 1. The spindle 5 thus causes a liquid jet to form as the material exits through the crucible orifice 1a, the jet in turn disintegrating into a cascading stream of material drops 60 as the material flows through the deposition section 40 and onto a traversable substrate 6 mounted with the deposition section 40.

Preferably, the spindle 5 is coupled to a piezoelectric oscillator (not shown) which vibrates the spindle 5 at a prescribed excitation frequency. Nominally, the oscillator and consequently the spindle is operated at an optimal excitation frequency f_{opt} as defined by Equation 1 below:

$$f_{opt} = 0.225\ U_j/d_{eff} \qquad \text{... Equation (1)}$$

wherein d_{eff} is the effective jet diameter and U_j is the jet velocity. See, e.g., J. Rayleigh, "On the Stability of Jets," Proceedings London Mathematical Society," vol. 10, pp. 4-13 (1879); D. Harmon, "Drop Sizes from Low Speed Jets," J. Franklin Inst., vol. 259, pp. 519-523 (1955). For most forming materials such as metal alloys or wax, e.g., a tin-antimony alloy or paraffin wax, f_{opt} is nominally between 1 to 50 kHz.

Other features of the drop deposition system 100 include: a position controller 2 in the control section 20 coupled to the piezoelectric oscillator and spindle 5 for controlling the vertical position and excitation frequency of the spindle 5; a position controllable platform 7 for supporting and positioning the traversable substrate 6 on which the molten material drops 60 are deposited; sensor leads 8 for coupling sensors within the deposition section 40; and a vacuum/gas line 9 for controlling the pressure inside the deposition section 40. A connection 10 to an external pressure source, preferably a pressure source using non-reactive gases such as

nitrogen or helium, is also provided for facilitating the flow of the molten metal from the crucible 1.

Referring now to FIG. 2, which is detailed sectional view of the crucible orifice 1a and the spindle 5, the orifice 1a is conically-shaped having a fixed outlet diameter d_0. The spindle 5 includes a conically-shaped spindle head 5a for cooperating with the conically-shaped orifice 1a wherein the spindle head 5a itself includes a slanted radial portion 5c resembling an arrowhead defined by slant angle θ, and a tip portion 5b. The dimension δ, which is the amount the lowermost tip of the spindle extends below the bottom of the crucible 1, varies depending upon the vertical position of the spindle 5 and spindle head 5a. As such, by controlling the vertical position of the spindle 5 via position controller 2, the spindle 5 with its spindle head 5a also functions as a means for varying the effective diameter or size d_{eff} of the crucible orifice 1a thereby varying the diameter or size of the liquid jet 50 expelled through the orifice 1a. The effective diameter d_{eff} of the orifice 1a and thus liquid jet 50 the according to FIG. 2 is defined by Equation (2) below:

$$d_{eff} = [d_0^2 - (d_0 - \delta \tan \theta)^2]^{1/2} \quad \text{... Equation (2).}$$

Preferably, the slant angle θ value ranges from 5 to 30 degrees, and the fixed size diameter d_0 of the conically-shaped orifice ranges from 10 μm to 1 mm depending upon the accuracy requirements of the object to be manufactured.

Thus, the conically-shaped spindle head 5a is designed to cooperate with the conically-shaped orifice 1a so as to regulate the amount and flow rate of the molten material exiting the crucible 1 and to produce a wide range of droplet sizes. The conically-headed spindle 5 can be controlled or moved vertically to any number of positions which are determined by the position controller 2. Molten material flowing towards the crucible orifice 1a follows the contour of the conically-spaced spindle head 5a and thus forms a circular liquid jet 50 having a diameter d_{eff} proportional to the amount of flow exited through the crucible orifice 1a. Since the spindle 5 is also subject to the excitation frequency discussed above, the circular jet 50 is then broken into cascading stream of droplets as the material flows towards the

traversable substrate 6. As a result, a wide range of diameters of the circular jet and thus droplets are obtained.

FIG. 3 shows a sectional view of a preferred embodiment of the crucible 1 shown in FIG. 1. The crucible 1, which is cylindrical in cross-section, has a vertical z-axis which passes through the center of the crucible orifice 306. Preferably, the crucible 1 is constructed of stainless steel coated with chromium or other similar materials capable of withstanding temperatures up to and exceeding 1000 °C.

As shown in FIG. 3, the crucible 1 includes: the conically-shaped crucible orifice 306 having a fixed outlet diameter d_0; a first horizontal annular surface 304 extending radially from the z-axis of the crucible having an elevation h_0 along the z-axis from the lower surface of the crucible with an inner contour defined by the diameter of the orifice and an outer contour defined by a first diameter d_1 greater than d_0; a second horizontal annular surface 302 extending radially from the z-axis of the crucible having an elevation $h_1 + h_0$ from the lower surface of the crucible with an inner contour defined by the first diameter d_1 and an outer contour defined by a second diameter d_2 greater than d_1; and an outer cylindrical wall 301 having an inner contour defined by the second diameter d_2.

FIG. 3 further shows the liquid level at an elevation $h_2 + h_1 + h_0$ and pressure values P_C, P_1, P_0 and P_∞ at various points within the crucible with P_C representing the pressure applied to the molten liquid at the elevation $h_2 + h_1 + h_0$ via an external pressure source, e.g., gas, P_1 representing the pressure of the liquid at the elevation $h_1 + h_0$, P_0 representing the pressure of the liquid at the elevation h_0, and P_∞ represents the pressure of the liquid at the crucible orifice 306.

In summary, an improved crucible and spindle apparatus has been disclosed for use in a drop deposition system. The apparatus as disclosed herein is used to form variable diameter liquid jets from which variable diameter material drops 60 are formed.

Although the present invention has been described in connection with particular embodiments thereof, it is to be understood that such embodiments are susceptible of modification and variation without departing from the inventive

concept disclosed. All such modifications and variations, therefore, are intended to be included within the spirit and scope of the appended claims.

CLAIMS

1. In a system for manufacturing a three-dimensional object by deposition of molten material drops on a substrate, an apparatus for producing said molten material drops comprising:

a crucible for holding a reservoir of molten material;

a conically-shaped orifice having a fixed outlet diameter disposed in the bottom of said crucible through which a jet of said molten material flows towards said substrate; and

an oscillating mechanical member for breaking said flow of molten material into said molten material drops, said member having a conically-shaped head for cooperating with said orifice and for varying the effective size of said orifice, said conically-shaped head comprising a slanted radial portion and a tip portion extending through the orifice, the effective diameter d_{eff} of said orifice and said jet being defined by the equation $d_{eff} = [d_0^2 - (d_0 - \delta \tan \theta)^2]^{1/2}$, wherein d_0 represents said fixed outlet diameter, δ represents the amount of said tip portion extending through the orifice, and θ represents a slant angle corresponding to said slanted radial portion.

2. The apparatus according to claim 1, wherein said crucible comprises:

a first annular surface extending radially from the center of the crucible having an elevation h_0 above the lower surface of said crucible, and an outer contour defined by a first diameter d_1 greater than d_0;

a second annular surface extending radially from the center of the crucible having an elevation $h_1 + h_0$ above the lower surface of said crucible, an inner contour defined by the first diameter d_1, and an outer contour defined by a second diameter d_2 greater than d_1; and

an outer cylindrical wall having an inner contour defined by the second diameter d_2.

3. The apparatus according to claim 1, wherein said oscillating mechanical member oscillates at a frequency f_{opt} defined by the equation $f_{opt} = 0.225 U_j/d_{eff}$, wherein d_{eff} is the effective diameter of said jet and U_j is the velocity of said jet through said orifice.

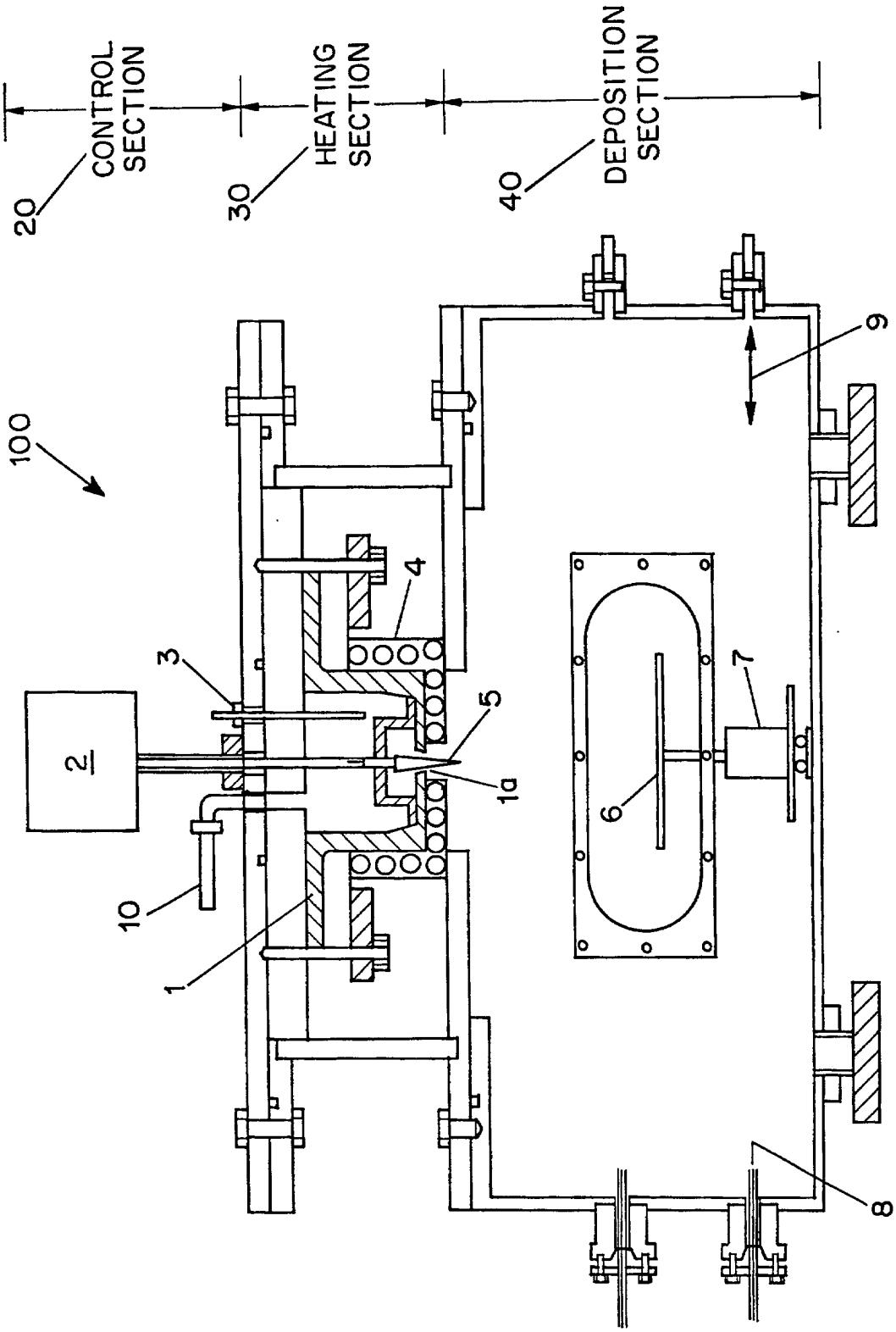
CONTROL SECTION
HEATING SECTION
DEPOSITION SECTION
20
30
40
100
9
4
3
5
1a
2
7
6
10
1
8

FIG. 1

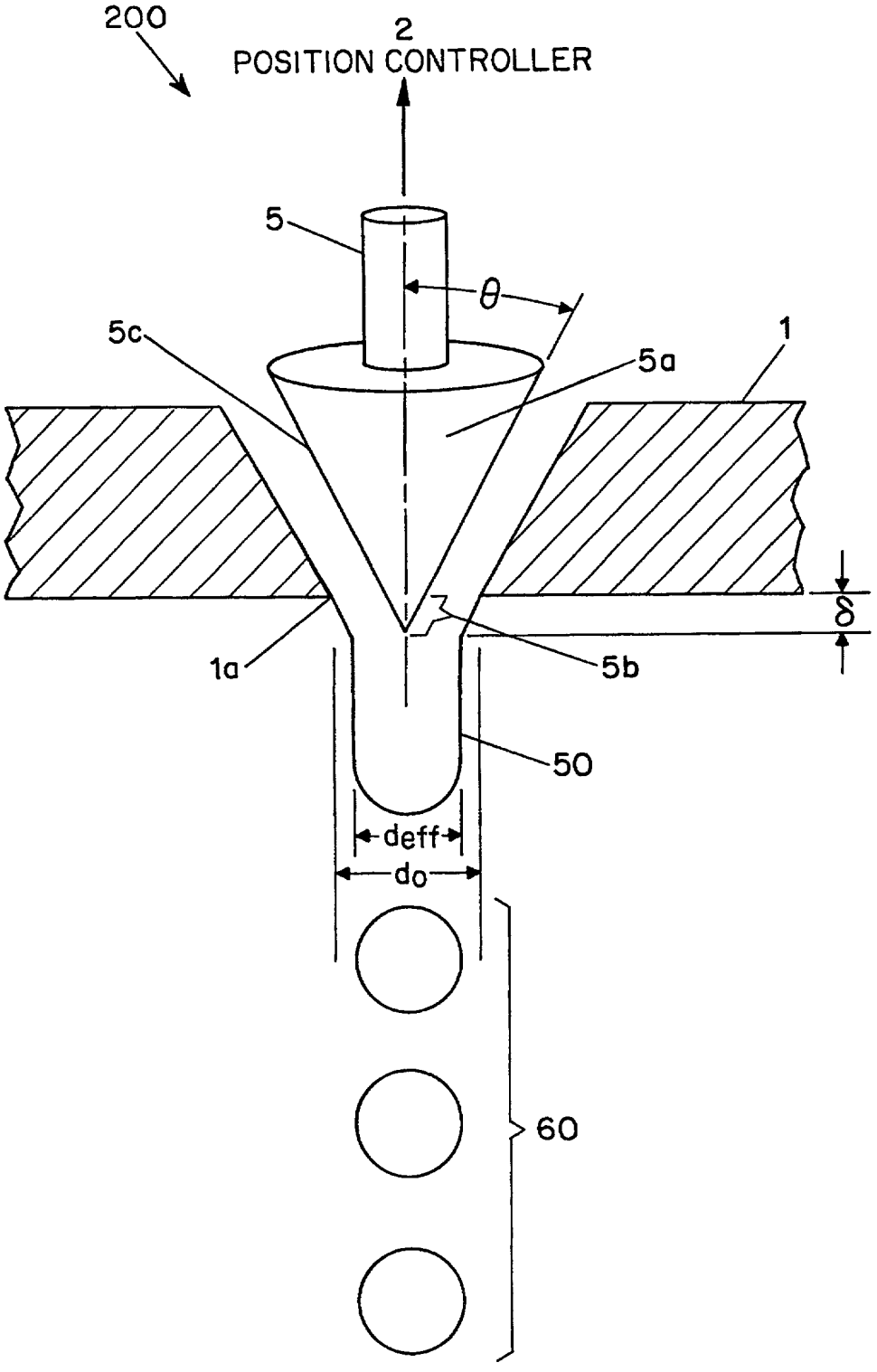

FIG. 2

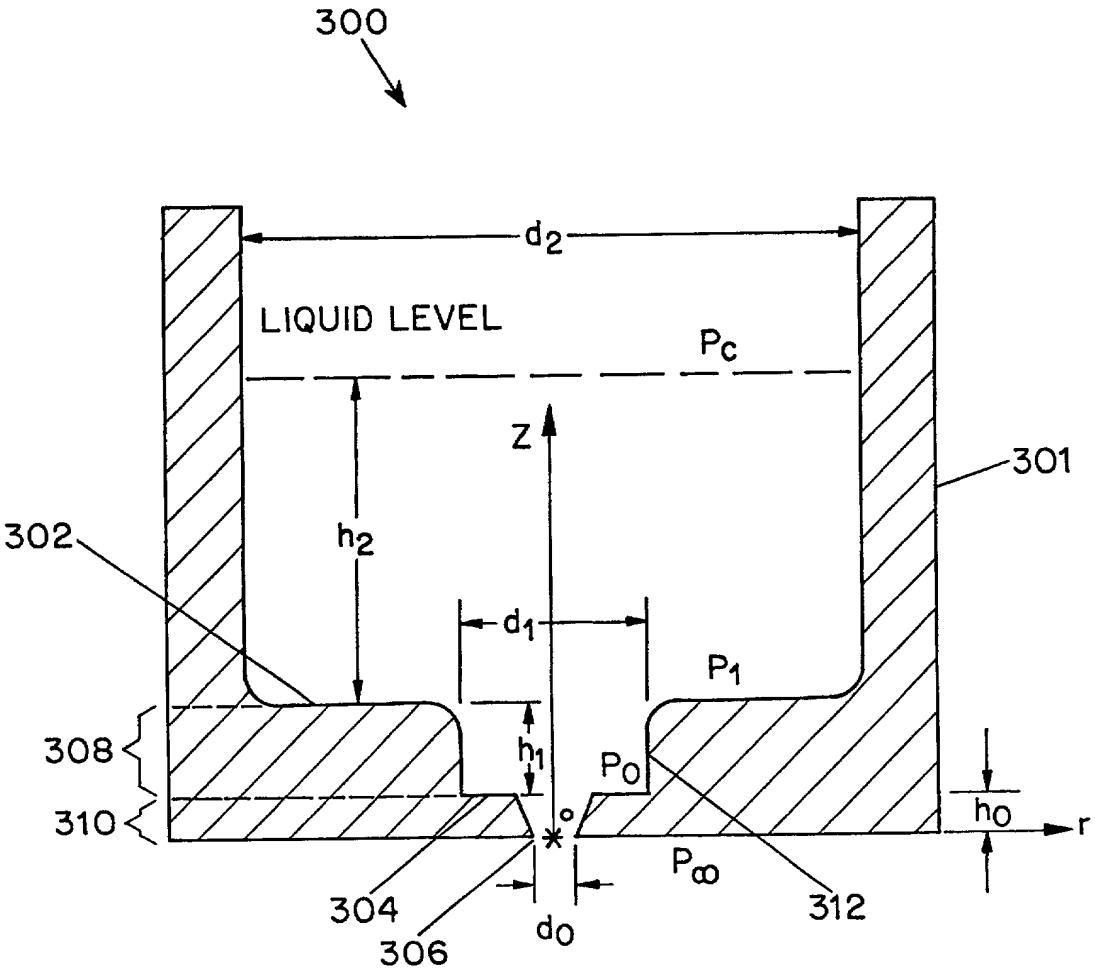
300
d2
LIQUID LEVEL
Pc
Z
301
302
h2
d1
P1
308
h1
P0
310
h0
r
P∞
304
312
306
d0

FIG. 3

COMBINED DECLARATION AND POWER OF ATTORNEY

(Original, Design, National Stage of PCT, Divisional, Continuation or C-I-P Application)

As a below named inventor, I hereby declare that:
My residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

CRUCIBLE AND SPINDLE FOR A VARIABLE SIZE DROP DEPOSITION SYSTEM

This declaration is of the following type:

[] original
[] design
[X] national stage of PCT.
[] divisional
[] continuation
[] continuation-in-part (C-I-P)

the specification of which: *(complete (a), (b), or (c))*

(a) [X] is attached hereto.
(b) [] was filed on as Application Serial No. and was amended on *(if applicable).*
(c) [X] was described and claimed in PCT International Application No. PCT/US99/26946 filed November 16, 1999 on and was amended on *(if applicable).*

Acknowledgment of Review of Papers and Duty of Candor

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of the subject matter claimed in this application in accordance with Title 37, Code of Federal Regulations § 1.56.

[] In compliance with this duty there is attached an information disclosure statement. 37 CFR 1.98.

Priority Claim

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) of any foreign application(s) for patent or inventor's certificate or of any PCT International Application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT International Application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application on which priority is claimed

(complete (d) or (e))

(d) [] no such applications have been filed.
(e) [] such applications have been filed as follows:

PRIOR FOREIGN/PCT APPLICATION(S) FILED WITHIN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO SAID APPLICATION			
COUNTRY APPLICATION NO	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
			[ ] YES NO [ ]
			[ ] YES NO [ ]
			[ ] YES NO [ ]
ALL FOREIGN APPLICATION[S], IF ANY, FILED MORE THAN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO SAID APPLICATION			
			[ ] YES NO [ ]
			[ ] YES NO [ ]
			[ ] YES NO [ ]

Claim for Benefit of Prior U.S. Provisional Application(s)

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below:

Provisional Application Number	Filing Date

Claim for Benefit of Earlier U.S./PCT Application(s) under 35 U.S.C. 120

(complete this part only if this is a divisional, continuation or C-I-P application)

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior application(s) in the manner provided by the first paragraph of Title 35, United States Code § 112, I acknowledge the duty to disclose information as defined in Title 37, Code of Federal Regulations, § 1.56 which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

(Application Serial No.) (Filing Date) (Status) (patented, pending, abandoned)

(Application Serial No) (Filing Date) (Status) (patented, pending, abandoned)

Power of Attorney

As a named inventor, I hereby appoint Dana M. Raymond, Reg. No. 18,540; Frederick C. Carver, Reg. No. 17,021; Francis J. Hone, Reg. No. 18,662; Joseph D. Garon, Reg. No. 20,420; Arthur S. Tenser, Reg. No. 18,839; Ronald B. Hildreth, Reg. No. 19,498; Thomas R. Nesbitt, Jr., Reg. No. 22,075; Robert Neuner, Reg. No. 24,316; Richard G. Berkley, Reg. No. 25,465; Richard S. Clark, Reg. No. 26,154; Bradley B. Geist, Reg. No. 27,551; James J. Maune, Reg. No. 26,946; John D. Murnane, Reg. No. 29,836; Henry Tang, Reg. No. 29,705; Robert C. Scheinfeld, Reg. No. 31,300; John A. Fogarty, Jr., Reg. No. 22,348; Louis S. Sorell, Reg. No. 32,439; Rochelle K. Seide Reg. No. 32,300; Gary M. Butter, Reg. No. 33,841; Marta E. Delsignore, Reg. No. 32,689; Lisa B. Kole, Reg. No. 35,225 and Anthony Giaccio, Reg. No. 39,684 of the firm of BAKER & BOTTS, L.L.P., with offices at 30 Rockefeller Plaza, New York, New York 10112, as attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith

SEND CORRESPONDENCE TO:	DIRECT TELEPHONE CALLS TO:
BAKER & BOTTS, L.L.P. 30 ROCKEFELLER PLAZA, NEW YORK, N.Y. 10112 CUSTOMER NUMBER: 21003	BAKER & BOTTS, L.L.P. (212) 705-5000

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

FULL NAME OF SOLE OR FIRST INVENTOR	LAST NAME TSENG	FIRST NAME AMPERE	MIDDLE NAME A.	
RESIDENCE & CITIZENSHIP	CITY Phoenix AZ	STATE or FOREIGN COUNTRY Arizona	COUNTRY OF CITIZENSHIP United States	
POST OFFICE ADDRESS	POST OFFICE ADDRESS 4946 E. Cheery Lynn Road	CITY Phoenix	STATE or COUNTRY Arizona	ZIP CODE 85018
DATE 05/07/01	SIGNATURE OF INVENTOR			
FULL NAME OF THIRD JOINT INVENTOR, IF ANY	LAST NAME	FIRST NAME	MIDDLE NAME	
RESIDENCE & CITIZENSHIP	CITY	STATE or FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP	
POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE or COUNTRY	ZIP CODE
DATE	SIGNATURE OF INVENTOR			
FULL NAME OF FOURTH JOINT INVENTOR, IF ANY	LAST NAME	FIRST NAME	MIDDLE NAME	
RESIDENCE & CITIZENSHIP	CITY	STATE or FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP	
POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE or COUNTRY	ZIP CODE
DATE	SIGNATURE OF INVENTOR			
FULL NAME OF FIFTH JOINT INVENTOR, IF ANY	LAST NAME	FIRST NAME	MIDDLE NAME	
RESIDENCE & CITIZENSHIP	CITY	STATE or FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP	
POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE or COUNTRY	ZIP CODE
DATE	SIGNATURE OF INVENTOR			
FULL NAME OF SIXTH JOINT INVENTOR, IF ANY	LAST NAME	FIRST NAME	MIDDLE NAME	
RESIDENCE & CITIZENSHIP	CITY	STATE or FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP	
POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE or COUNTRY	ZIP CODE
DATE	SIGNATURE OF INVENTOR			

Check proper box(es) for any added page(s) forming a part of this declaration

[] Signature for ninth and subsequent joint inventors. Number of pages added _____.

[] Signature by administrator(trix), executor(trix) or legal representative for deceased or incapacitated inventor. Number of pages added _____.

[] Signature for inventor who refuses to sign, or cannot be reached, by person authorized under 37 CFR 1.47. Number of pages added _____.